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1987 / 11

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EVALUATION OF THE EXAC MASS FLOWMETER

J.D. MacLeod

Division of
Mechanical Engineering

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EVALUATION OF THE EXAC MASS FLOWMETER

ÉVALUATION DU DÉBITMÈTRE EN MASSE EXAC

J.D. MacLeod

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ABSTRACT

This report describes the work performed at the Engine Laboratory to evaluate the EXAC mass flowmeter. A description of the installation procedures, and comparison of test results against a calibrated volumetric flow measurement system are included. In addition, attempts to interface a computer to the EXAC are outlined, and recommendations on the overall suitability of this mass flow meter are presented.

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EVALUATION OF THE EXAC MASS FLOWMETER

1.0 INTRODUCTION

The Engine Laboratory was tasked by MDS Aero Support to evaluate the EXAC mass flowmeter (Ref.1,2), with regards to its accuracy and the suitability of this device in the engine test cell environment. The Engine Laboratory has extensive experience with turbine meters, which measure volumetric flow, but require specific gravity, viscosity and fuel temperature to infer mass flow. The EXAC flowmeter was capable of measuring mass flow directly, which is ideal for use in the field, where specific gravity and viscosity are not readily available.

To evaluate the EXAC, the device was installed in series with existing turbine meters in the fuel delivery system of the Allison T56 gas turbine in #2 test cell. The evaluation procedures included observations on the installation and operation of the unit in general, and more specifically, a comparison of the flow measurement with those of the turbine meters. In addition, an attempt was made to interface a computer to the EXAC, to allow for automated data acquisition.

2.0 INSTALLATION DESCRIPTION

The EXAC mass flowmeter, model EX120, was installed in three different configurations in #2 test cell. In the first configuration, the flow sensor (Figure 1) was placed in the fuel line, half way between the engine fuel control and the facility turbine meters. Approximately two metres of flexible fuel line were between the engine and the EXAC sensor and between the sensor and the turbine meters upstream. The flexible hoses were attached directly to the flanges of the sensor unit.

For the second set-up, the sensor was moved to a position one metre upstream of the turbine meters. Once again, the flexible lines were connected directly to the sensor. In both configurations, the sensor was placed on a foam pad sitting on the concrete floor.

For the final configuration, the EXAC sensor was installed exactly as described in the installation instruction manual (Table 2, Figure 4), in the same location as the first set-up.

The Series 7100 Transmitter (Figure 2) was placed in the control room and connected to the sensor with a 15 metre cable, as described in the manual (Ref.3).

The NRC fuel flow measurement system consisted of two one-half inch Flow Technology Inc. turbine meters (S/N 802969 and 802968), connected in series. These meters had recently been calibrated using NRC's ballistic flow calibrator which is traceable to the National Bureau of Standards through the manufacturer, FTI. The turbine meters were monitored by an automated data acquisition system, and their output averaged for comparison purposes.

3.0 TEST RESULTS

A total of 12 test runs were performed with the EXAC flowmeter installed in the fuel system. In the first configuration (run numbers 39 to 41), the results (Table 3) were very encouraging, with the difference between the EXAC and the turbine meters being about one percent (Figure 7). Even the totalized reading agreed well with the NRC Neptune flowmeter, at the completion of each test. However, during testing of the second configuration (run numbers 42 to 45), a step shift in the EXAC output was noticed (Figure 8). The cause of this shift was later found to be a result of a change in the calibration constants (see Section 4.0). The third configuration (run numbers 46 to 50), exhibited the same shift until the constants were restored to their original values (run number 50).

It was apparent during the testing that the configuration had no obvious effect on the performance of the EXAC. Configuration two was an attempt to see if the pressure fluctuations at the fuel control inlet were propagating upstream and affecting the EXAC sensor. This was found not to be the case. Some hunting of the transmitter reading had been observed during testing of configuration one, however, increasing the time constant to four seconds, stabilized the reading.

There was some evidence to indicate that the difference between the EXAC and the turbine meters was greater at the lower flows, while gradually decreasing as the flow increased. While the device was tested using different fuel temperatures (285-295 K range), there was no sign of a temperature influence on the results. The sensor, placed less than two metres from the engine did not experience any fluctuations as a result of noise, vibration or electrical interference.

4.0 COMPUTER INTERFACE

To establish a better comparison between the output of the mass flowmeter and the turbine meters, a computer interface with the EXAC was attempted. Since some minor hunting had been observed in the transmitter, it was thought that the computer would provide a better time-averaged value for the mass flow recorded by the EXAC.

The transmitter wiring compartment (Figure 3) has both RS232 and RS422 connectors for interfacing with an external or remote terminal. The pin arrangements for these connectors are shown in figure 6. Instructions on how to communicate with the transmitter were extremely poor. It was later discovered that the communication message protocol documentation had not been sent with the unit.

A Visual 100 series terminal was used to interface with the transmitter, since a Lear Siegler model (as stated in the instruction manual) was not available. The first step in establishing the communication link with the transmitter was to set up the Configuration Card (Figure 5) in the transmitter. Some difficulty was encountered in setting the delicate switches, while maintaining a pass in the diagnostic self-test, during start-up. This appeared to be a hit or miss kind of operation, with one in

four attempts resulting in a diagnostic failure. To complicate matters, an error in the Configuration Card set-up instructions caused many delays. This led to the conclusion that channel 00 was not a valid communication port, in contradiction to the statement in the manual.

After some initial problems, communication between the EXAC and the terminal was established through the RS232 connector, in both the on-line and local modes. In the on-line mode, a series of menus were found. There was no reference to these menus in the operation manual. Furthermore, it was discovered that the calibration constants could be altered using the parameter setting menu. The manual states that this could only be done using the asynchronous communication message protocol through the RS422 connector.

Several unusual problems occurred during the computer interfacing which created doubts as to the suitability of this device for use in an automated data acquisition system. First, the communication link would fail for no apparent reason, and attempts to restore the link were extremely difficult. Second, power interruptions caused internal parameter changes, which in one case, caused the EXAC to record negative flow rate of ever increasing magnitude while the fuel system was shut off. Third, the output of the EXAC is specifically intended to be received by a Lear Siegler device only. To speed up the display process, the EXAC software sends graphics control characters directly to the terminal screen. For non-compatible devices, extraneous control characters showed up, which made it difficult to examine the incoming data. To decipher data coming from the EXAC transmitter, a special software program would be required to filter out the graphics control characters, and interpret the data stream.

Finally, one general complaint about communication with the transmitter. Those parameters which one might want to periodically change (eg. time constant, units, baud rate, etc.) could only be altered using the DIP switches inside the transmitter, which were awkward to reach. In contrast, those parameters which should not have to be changed, such as the calibration constants, could be changed at the push of a button using the appropriate menu.

5.0 SUMMARY AND RECOMMENDATIONS

The results of this evaluation may be summarized as follows:

a) When operating properly, the agreement between the EXAC and turbine flowmeters was very good (less than one percent).

b) Interfacing the EXAC to a computer was extremely difficult, and produced unpredictable results.

c) The flow sensor is relatively easy to install, and did not require any special installation precautions.

Based on the experience acquired with the EXAC during the evaluation procedure, it is recommended that the EXAC not be installed in a

test cell environment at this point in time. The reasons for this are based on the unreliability of the device on a day to day basis. The cause for intermittent operation needs to be resolved and the documentation needs improvement. The lack of proper documentation makes it difficult to incorporate into an automated data acquisition system. In addition, the complexity of the transmitter requires an electronics and microprocessor software expert to maintain it.

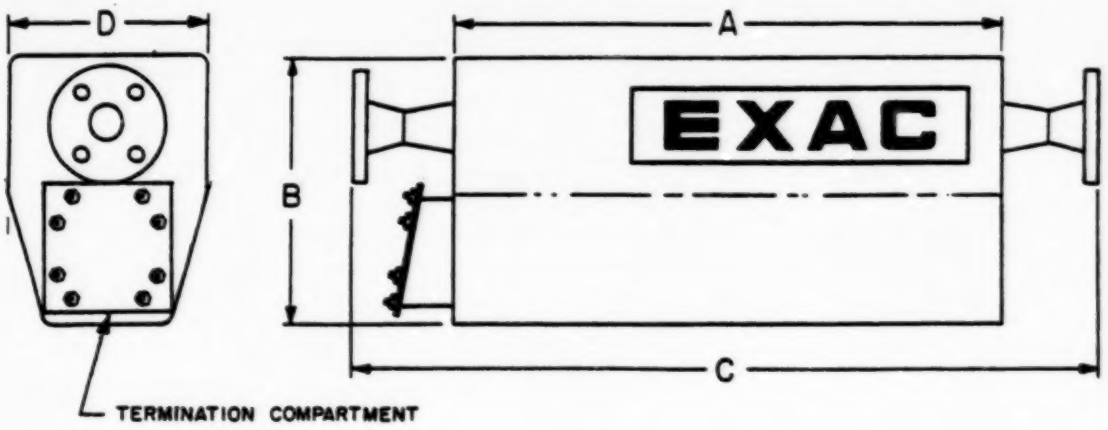
Some preliminary discussions with another test facility indicated unaccounted for temperature effects in some mass flow meters. For this reason, it is further recommended that the EXAC mass flowmeter undergo more exhaustive laboratory testing to determine its accuracy over its full operating range, and over a wide range of fuel temperatures. This study should be performed under controlled condition, traceable to National Standards. Such a comprehensive project has been proposed to National Defence by NRC.

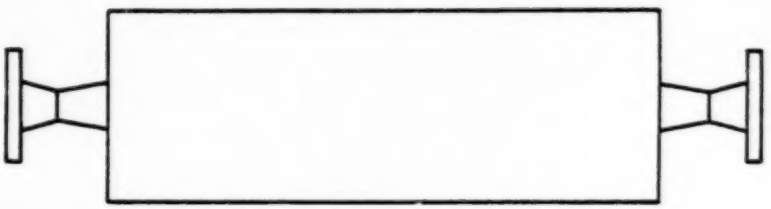
6.0 REFERENCES

1. Letter from A. Hesketh, MDS Aero Support to D. Rudnitski, Head Engine Laboratory, dated July 23, 1986.

2. Letter from D. Rudnitski, Engine Laboratory to A. Hesketh, MDS Aero Support, dated August 8,1986.

3. MODEL 1100 True Mass Flowmeter Installation, Start-up, and Maintenance Manual, 1985 EXAC Corporation.





SERIES	A INCHES	B INCHES	C INCHES	D INCHES	WEIGHT LBS
EX 120	$15\frac{1}{2}$	8	$21\frac{5}{8}$	$6\frac{1}{8}$	23

Figure 1: EX 120 Mass Flow Sensor Outline

EXAC
1370 DELL AVENUE
CAMPBELL CALIFORNIA 95008 (408) 374-6810

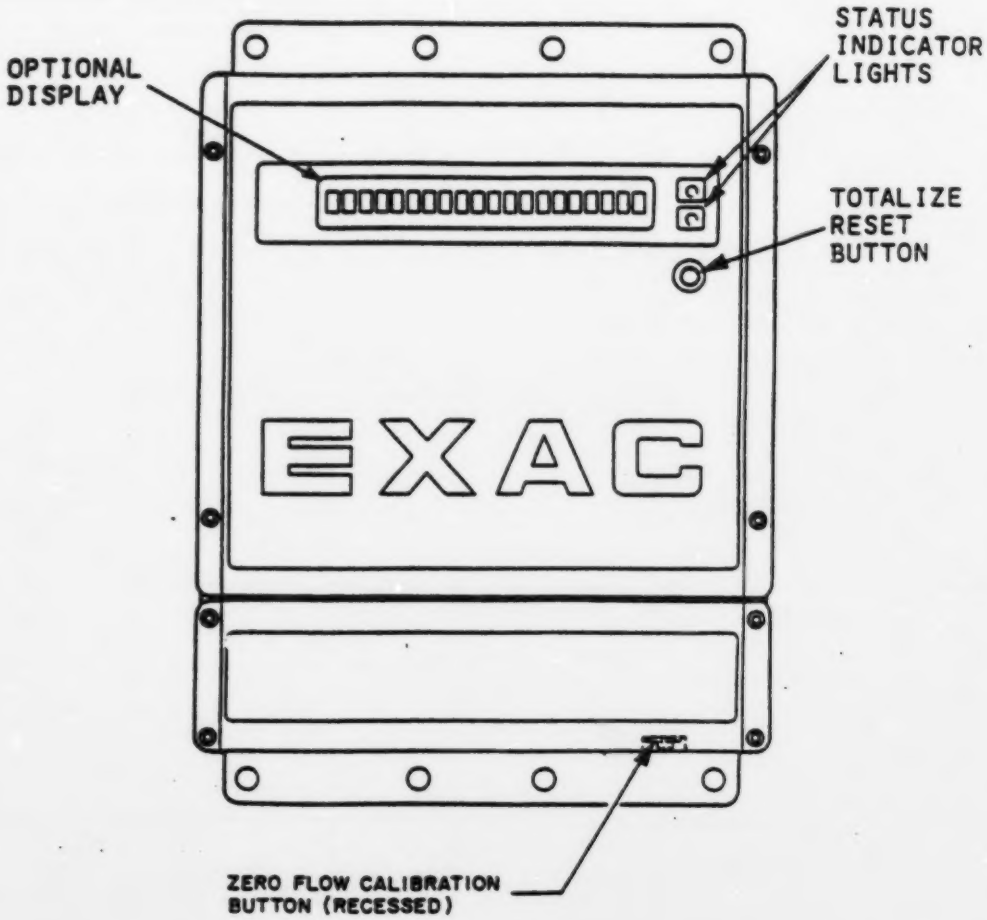


FIGURE 2: SERIES 7100 TRANSMITTER

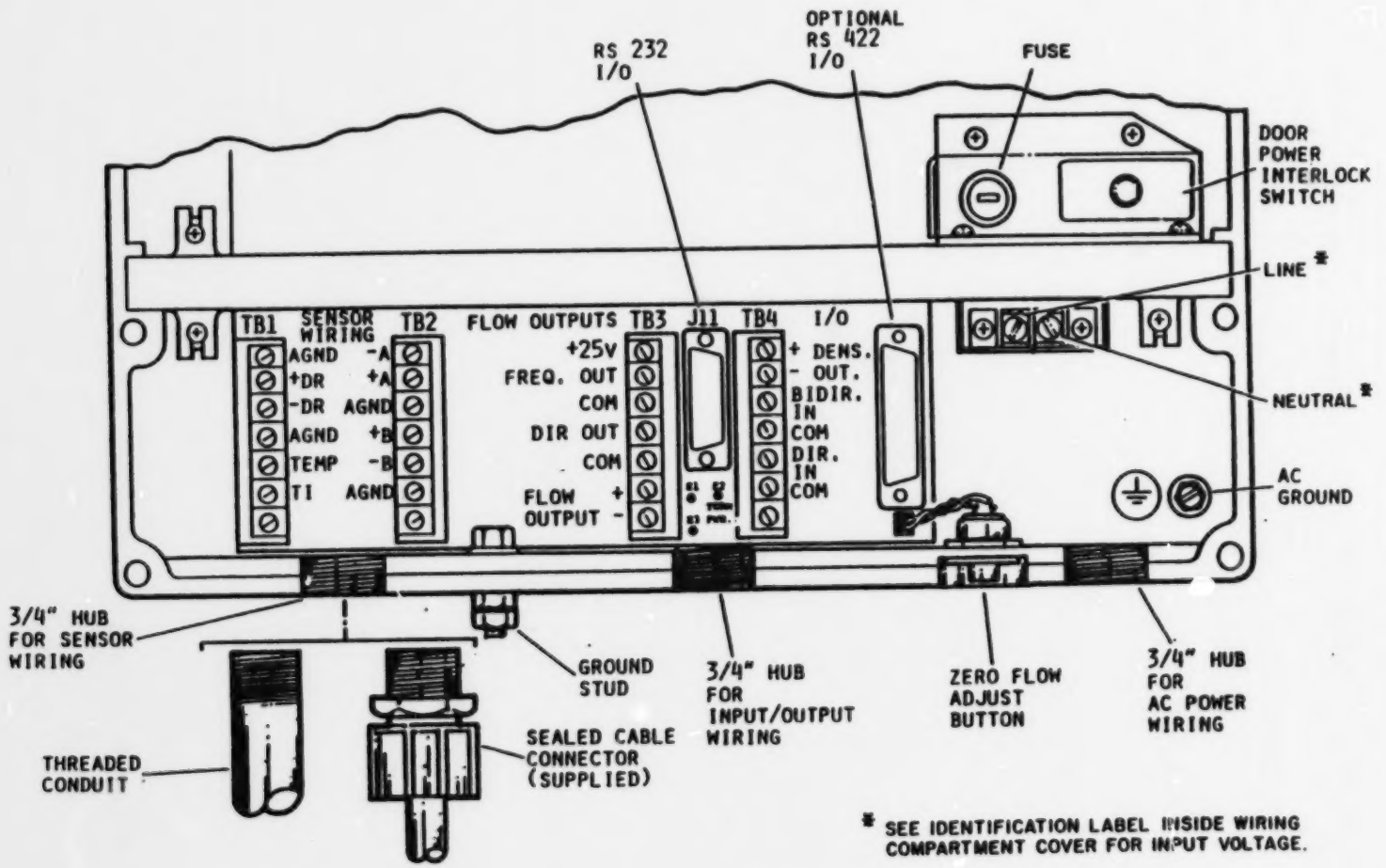


FIGURE 3: SERIES 7100 TRANSMITTER WIRING COMPARTMENT

EXAC 1370 DELL AVENUE CAMPBELL, CALIFORNIA 95008 (408) 374-6810

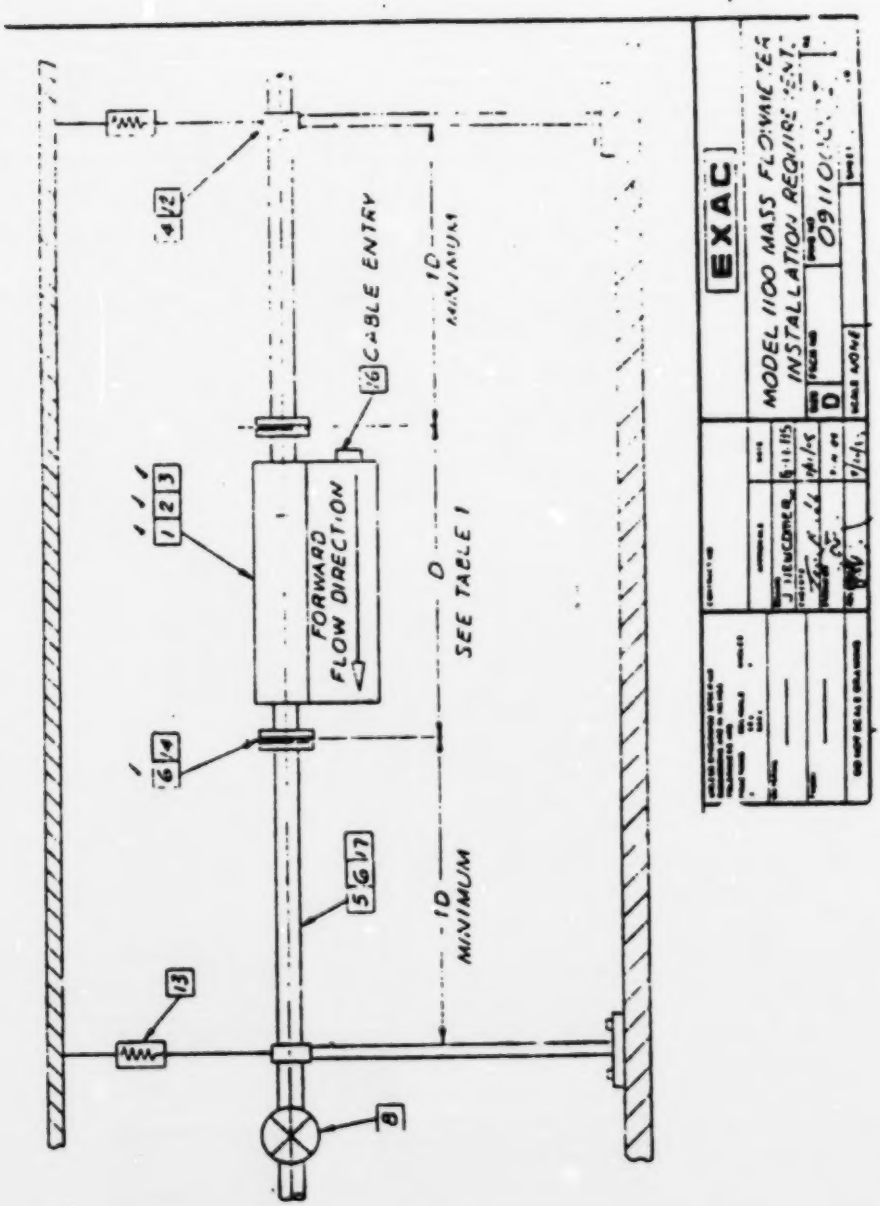


Figure 4: Flowmeter Installation Requirement

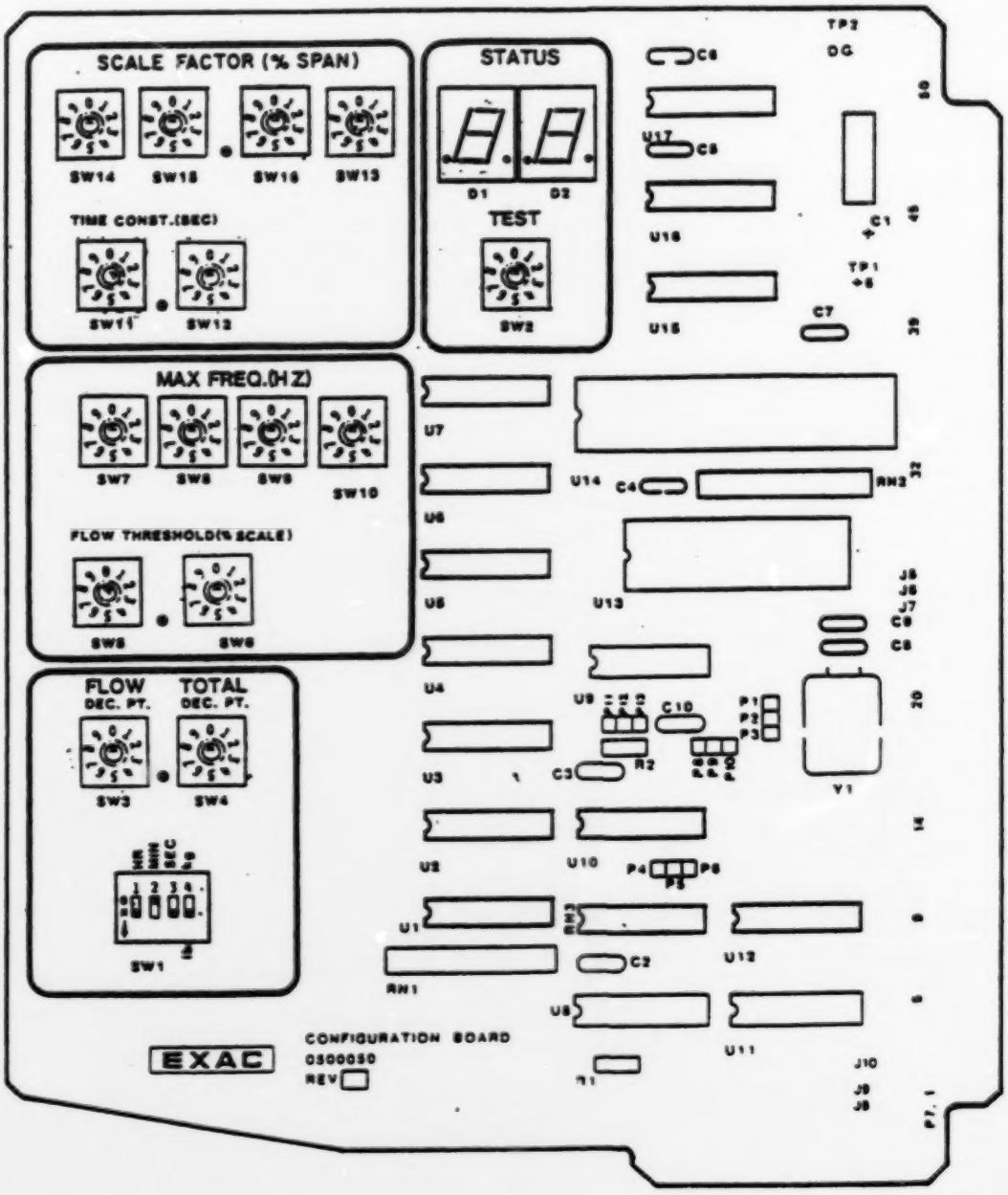
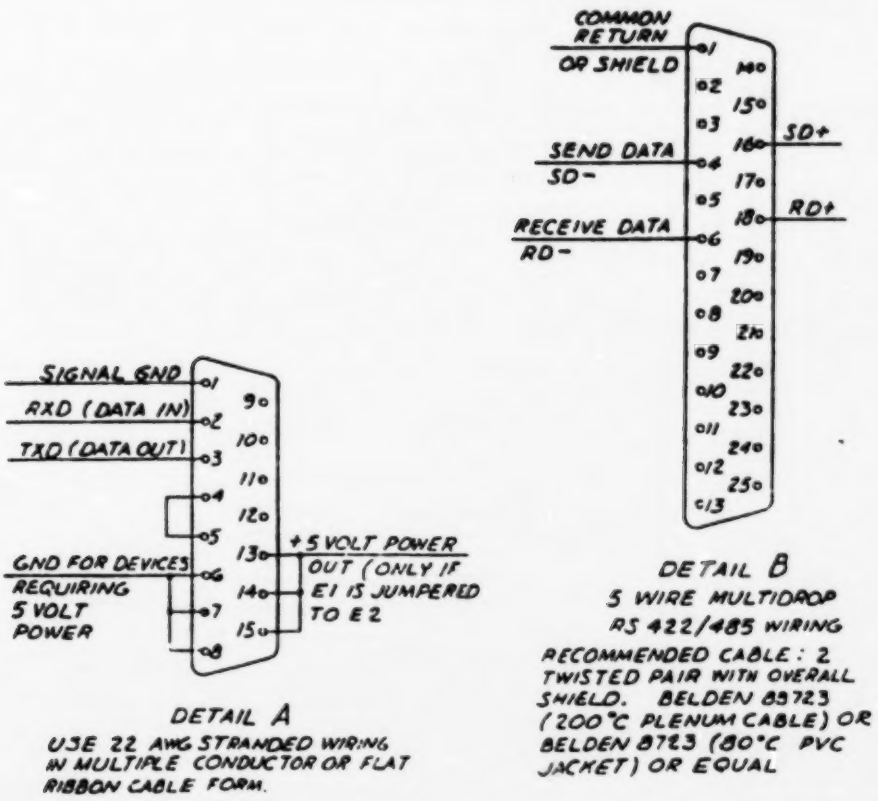


FIGURE 5: CONFIGURATION CARD

Figure 6: Computer Interface Connections



DETAIL A

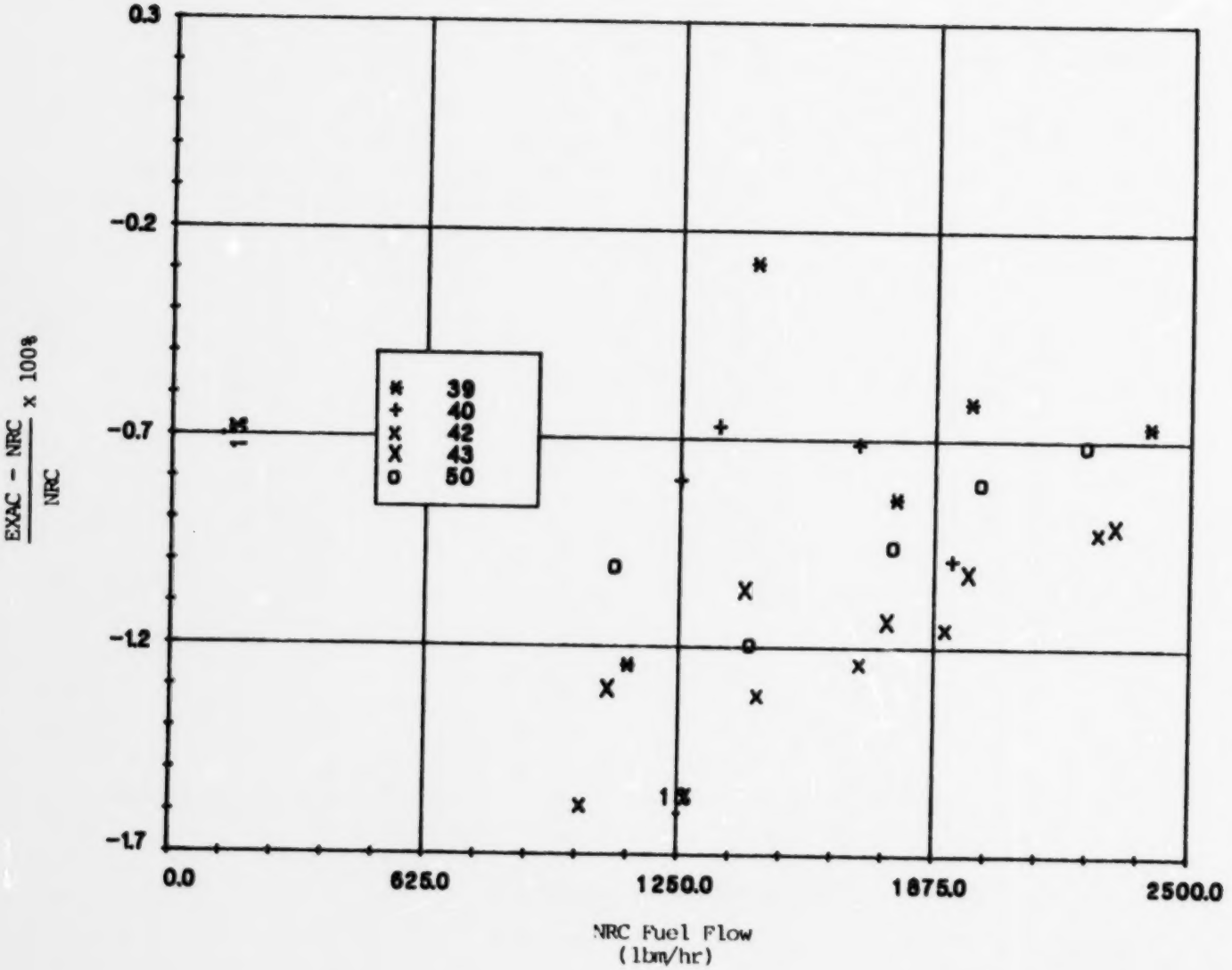
USE 22 AWG STRANDED WIRING IN MULTIPLE CONDUCTOR OR FLAT RIBBON CABLE FORM.

DETAIL B

5 WIRE MULTIDROP RS 422/485 WIRING

RECOMMENDED CABLE: 2 TWISTED PAIR WITH OVERALL SHIELD. BELDEN 89723 (200°C PLENUM CABLE) OR BELDEN 8723 (80°C PVC JACKET) OR EQUAL

Figure 7: Flowmeter Comparison/Repeatability



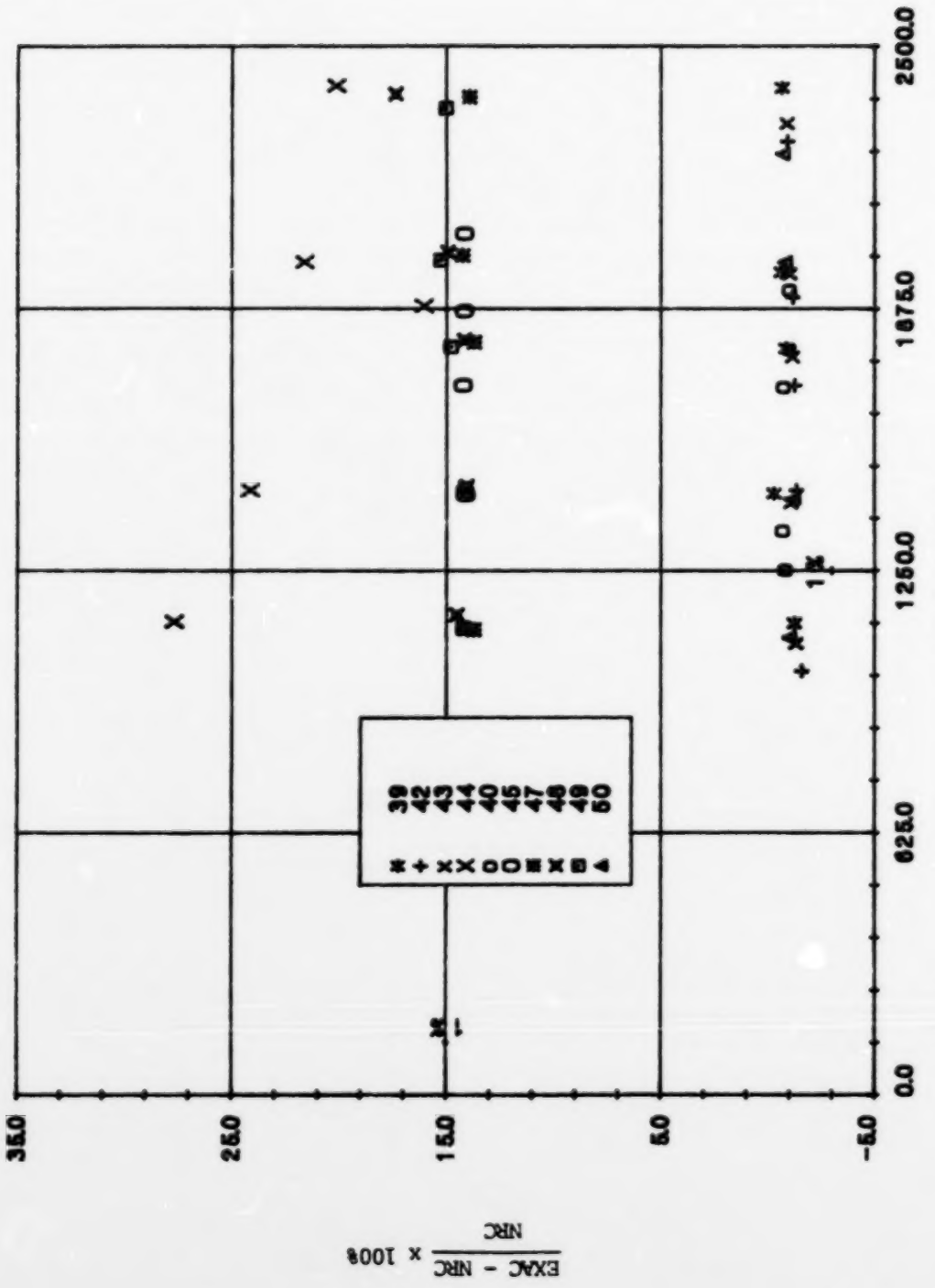


Figure 8: EXAC Flow Shift

Table 1: Series 7100 Transmitter Specifications

SERIES 7100 TRANSMITTER

Environment - Series 7100 Transmitter

Ambient Temperature:	-15°C to +55°C (+5°F to +131°F)
Relative Humidity:	0 to 98% R.H. (non-condensing)
Corrosion Resistance:	Housing material, low copper content aluminum alloy with polyurethane coating
Enclosure:	NEMA 4X construction
Weight:	40 pounds
Voltage supply:	115/220/240 VAC ± 10%
Frequency:	50/60 Hz
Power:	40 watts-max.

Outputs - From Series 7100 Transmitter

Frequency: 0-10,000 Hz maximum (field adjustable) corresponding to flow rate; 0-15V pulses into 10 kohms minimum load

Mass Flow Analog: 4-20mA corresponding to flow rate; 750 ohms maximum loop resistance

Density Analog: 4-20mA corresponding to 0 to 2.0 grams per cubic centimeter (specific gravity, relative to water at 65°F) (optional)*

Digital: RS232C - 25 ft. max., 9600 baud, ASCII Format (for use with CRT terminal or hand-held terminal)
RS422 - 4,000 ft. max., 9600 baud, ASCII Format (optional)

Digital I/O Communications Capability:
RS232C - Allows use of a CRT terminal to read measured rate and totalized flow.
RS422 - Permits communication with process control computer for data and meter reconfiguration.

Displays - On Series 7100 Transmitter (Optional)

Flowrate: 4 digits, selectable decimal point

Total Flow: 7 digits, selectable decimal point, local or remote reset. (6 digits if decimal point is used)

Optional non-volatile RAM memory available to retain flow total during power OFF. (Battery back up)

Flow Units: lbs or kgs, per second, minute or hour, switch selectable.

Indicator lights: Flow direction, flow/no flow, power on, failure indication.

Table 2: Flowmeter Installation Instructions

NOTES, UNLESS OTHERWISE SPECIFIED.

1. LOCATE SENSOR AT LOWEST PRACTICAL LEVEL IN THE SYSTEM.

2. INSTALL SENSOR IN LEVEL, HORIZONTAL POSITION WITH ITS HORIZONTAL CENTER LINE IN LINE WITH CENTER LINE OF THE PIPING BETWEEN THE SUPPORTS.

3. DO NOT REST SENSOR ON ANY OBJECT; DO NOT PLACE ANY OBJECT ON THE SURFACE OF THE SENSOR.

4. USE HANGERS OR SUPPORTS THAT ARE THE SAME SIZE AS THOSE ALREADY IN USE IN THE SYSTEM.

5. USE ONLY RIGID PIPE IN THE SYSTEM; DO NOT CONNECT FLEXIBLE TUBING OR HOSE DIRECTLY TO THE SENSOR.

6. DO NOT BEND OR DISTORT PIPE TO FORCE A FIT WITH THE FLANGES ON THE SENSOR. DO NOT TWIST THE SENSOR FLANGES RELATIVE TO EACH OTHER.

7. PIPING SYSTEM FLANGES MUST BE PARALLEL TO SENSORS FLANGES WITHIN ± 1/32".

8. USE HIGH QUALITY, POSITIVE SEAL VALVE TO ENSURE PROPER ZERO CALIBRATION (CUSTOMER PROVIDED). LOCATE VALVE, DOWNSTREAM FROM SENSOR, BEYOND THE PIPE HANGER OR SUPPORT CLOSEST TO THE SENSOR.

9. PIPING IN WHICH SENSOR IS INSTALLED MUST BE AS FREE OF VIBRATION AS POSSIBLE.

10. LOCATE SENSOR AS FAR AS POSSIBLE FROM ANY SOURCE OF ELECTRICAL NOISE (LARGE MOTORS, TRANSFORMERS, OR POWER SWITCHES/CONTACTORS).

11. FOLLOW LOCAL CODES AND ACCEPTED PIPING PRACTICES WHEN INSTALLING SENSOR.

12. FIT AND TIGHTEN PROCESS CONNECTIONS TO SENSOR BEFORE ASSEMBLING THE MOUNTING CLAMPS. FIT UP OF MOUNTS TO THE PROCESS PIPE MUST NOT CAUSE LARGE BENDING STRESSES AT THE CONNECTIONS TO THE SENSOR. THE MOUNTS MUST BE TIGHT ON THE PIPE AND NOT ALLOW AUDIBLE RATTLING OR BUZZING OF HARDWARE. IF VIBRATION LEVELS OF THE SENSOR FLANGES RISES DRAMATICALLY AT THE TIME OF FINAL FIT UP, REALIGN PIPING AND MOUNTS TO SENSOR. THIS CONDITION GENERALLY INDICATES THAT THE SENSOR IS BEING HIGHLY STRESSED.

13. AN ALTERNATE MOUNTING TECHNIQUE WHEN HIGH VIBRATION LEVELS EXIST. USE GRINNELL (OR EQUIVALENT) SPRING OR SHOCK ABSORBER ASSEMBLIES IF CEILING OR BEAM VIBRATION IS LOW.

14. IF LADISH TRI-CLAMP END FITTINGS ARE USED, A LADISH 13PKP CLAMP IS REQUIRED.

15. INTRINSICALLY SAFE INSTALLATIONS MUST BE INSTALLED IN ACCORDANCE WITH THE INSTALLATION, START-UP AND MAINTENANCE MANUAL.
FAILURE TO OBSERVE THE WIRING CONNECTIONS FOR THIS DRAWING WILL VOID INTRINSIC SAFETY STATUS OF THE METER AND COULD BE EXTREMELY HAZARDOUS!

16. MOUNT SENSOR SO THAT FORWARD FLOW ENTERS SENSOR AT "CABLE END".

17. THE STRAIGHT PIPE RUNS BEFORE AND AFTER THE SENSOR AS SHOWN IN THE DIAGRAM ARE NOT REQUIRED. MINIMUM DISTANCE FROM END FITTINGS TO PIPE SUPPORT MUST BE MAINTAINED REGARDLESS OF PIPING CONFIGURATION.

Table 3: Flowmeter Comparisons

Measurements in pounds/hour

Run Number	NRC	EXAC	% DIFF
39	1124	1110	-1.24
	1435	1430	-.31
	1780	1765	-.84
	1962	1950	-.61
	2401	2385	-.67
40	1250	1240	-.84
	1344	1344	-.71
	1687	1675	-.71
	1919	1900	-.99
41	1929	1914	-.78
	1946	1930	-.85
	1326	1314	-.94
42	1010	994	-1.63
	1442	1423	-1.32
	1692	1671	-1.27
	1902	1880	-1.13
	2274	2253	-.95
43	1075	1061	-1.30
	1411	1396	-1.06
	1759	1739	-1.14
	1958	1938	-1.05
	2316	2295	-.91
44	1128	1440	27.7
	1442	1790	24.1
	1882	2184	16.1
	1986	2415	21.6
	2406	2890	20.1
45	1430	1632	14.1
	1692	1933	14.2
	1869	2134	14.2
	2054	2345	14.2
46	848	962	13.4
	1080	1226	13.6
	1390	1585	14.0
	1710	1950	14.6
	1912	2183	14.1
	2359	2692	14.1

Table 3: Flowmeter Comparisons (contd)

Run Number	NRC	EXAC	% DIFF
47	1108	1260	13.8
	1446	1650	14.1
	1794	2040	13.7
	2002	2287	14.2
	2379	2710	13.9
48	1144	1310	14.5
	1451	1655	14.1
	1800	2055	14.2
	2010	2310	14.9
	2386	2800	17.4
49	1112	1270	14.3
	1436	1640	14.2
	1784	2048	14.8
	1991	2295	15.3
	2352	2705	15.0
50	1089	1078	-1.01
	1422	1405	-1.16
	1772	1755	-.93
	1986	1970	-.83
	2244	2228	-.69

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4

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CORPORATE AUTHOR/PERFORMING AGENCY/AUTEUR D'ENTREPRISE/AGENCE D'EXÉCUTION

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NOTES

13

DESCRIPTORS(KEY WORDS)/MOTS-CLÉS

EXAC, mass flowmeter, turbine meter

14

SUMMARY/SOMMAIRE

Describes the evaluation of the EXAC mass flowmeter with existing NRC fuel flow measurement techniques to determine its suitability in a test cell environment.

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